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PRE-GLACIAL DRAINAGE IN THE VICINITY OF CINCINNATI; ITS RELATION TO THE ORIGIN OF THE MODERN OHIO RIVER, AND ITS BEARING UPON THE QUESTION OF THE SOUTHERN LIMITS OF THE ICE-SHEET.

By GERARD FOWKE.

For more than sixty miles below the mouth of the Little Miami, the Ohio river flows through a tortuous channel. The dial of a compass fixed on a steamer will, in that distance, make a complete circuit under the needle. Much of the way the outer curves sweep over rocky detritus fallen from rugged hills crowned with precipitous bluffs; opposite these the inner curves flow gently over sand-bars bordering terraced bottom lands. The variation in the width of the valley is considerable; at times the upland on one side recedes, and a wide bottom intervenes between its foot and the river; again, the hills approach each other until only a narrow strip of alluvial soil is found.

For fifty miles above the Little Miami different conditions prevail; the valley is more uniform in breadth, the hills have gentler slopes and more symmetrical contours. The geological formation within this area is identical, all of it lying in the Cincinnati or Hudson River group; measured vertically, there is about one foot of compact blue limestone to ten feet of gray or bluish clay. Such a combination does not readily lend itself to the construction of cliffs by atmospheric erosion; while the close texture of the clay and its extension below surface drainage lines, precludes such disintegration of lower strata as would result in cliffs due to great landslides or the downfall of large masses of rock. The topography above the Little Miami is normal, while the phenomena below that point are quite differ-

ent from what would be expected. An examination of the region, with a view to learning the reason of this diversity, resulted in some interesting discoveries.

It must be stated, however, that the work of deciphering the earth-written records has not been fully carried out. Many details are yet to be studied before an accurate map of the ancient drainage can be constructed, or a full explanation given of the causes which led to the establishment of the present water-courses. This work I had hoped to do before offering a paper on the subject; but circumstances have made it necessary that I should present an account of the part that has already been accomplished, and indicate the lines along which further investigations are required.

It will aid the reader in following the argument, to state at once that the Ohio, as an independent river, had no existence prior to the glacial epoch. Its present course, in so far as it now needs to be considered, was occupied entirely by a succession of unconnected creeks and ravines. There was a col at the eastern limit of Maysville, separating the waters of Cabin creek and Limestone creek. The former flowed north and east, and either joined Kinniconnick creek or followed Brush creek valley into Paint creek. The waters of Limestone followed their present direction to the mouth of the Little Miami, thence through the broad valley north of Cincinnati (see (A) on the accompanying map), and entered the present Mill creek valley somewhere in the vicinity of Carthage (B). The drainage to the east and north of this section has not yet been worked out.

There was a col between Little Miami and Licking, near the eastern line of Cincinnati, at the point (C); two very short ravines headed here and discharged, one toward either side. Another col, (D), existed at the lower end of Cincinnati. Between these last two cols, (C) and (D), the Licking flowed directly across the Ohio Valley, into Mill creek valley. Receiving old Limestone creek at (B), as above stated the Licking then passed on northward and entered the valley of the Great Miami at the city of Hamilton.

On the west side of the col (D) headed a ravine which followed the present bed of the Ohio to North Bend, the most northern point of this river below the mouth of Kanawha. At North Bend this creek or ravine cut through the hill to the north and entered what is now the bed of the Great Miami. From this point it may have followed the line of that stream northward and joined old Laughery creek in the vicinity of (E); or it may have continued a westerly course and fallen into old Laughery near the point (F). If the latter was the case, another ravine headed near by and flowed north along the Great Miami to (E). Further research will determine this drainage line.

Just west of North Bend was another col, at the point (G); but it seems to have been a continuation of the hill on the south, with a uniform slope across the present bed of the Ohio, forming the water-shed between the last mentioned ravine and old Laughery, and not a low divide between the heads of two smaller ravines tributary to these. Below this point, the mouth of the Great Miami is reached, in an ancient channel whose drainage is now reversed.

Proceeding down the Ohio, it will soon be found that this old stream had two main branches: one of them Laughery creek, now flowing into the Ohio two miles below Aurora; the other a creek rising somewhere near Sugar Creek Landing in Gallatin county, Kentucky, (K). Going up the river from this point, it will be observed that the valley gradually widens to the mouth of Grant's creek (J), where it is much wider than at any other place on the map; from here, high and wide bottoms on the Kentucky side extend as far as Petersburg (H). This greater width does not, however, properly belong to the eroded portion of the valley but is due to the fact that low foothills, produced by several ravines coming in along here, have been covered with glacial drift.

At (I) is "Split Rock," concerning which more is to be said.

Back of Petersburg is an abandoned channel (H), filled with drift and safe from the highest floods.

It is a noteworthy fact that from Sugar creek to Petersburg almost every creek that comes in on either side, whose source is in the hills, flows in a direction opposite to the Ohio until it reaches the bottom land, when it turns in a way to conform to the course of the river. It seems odd while going down the main stream, to look toward the head of nearly every tributary, large or small, whose valley is in the line of vision.

For eight miles below Aurora the Ohio, flowing on a rocky bottom, closely hugs the Indiana side; from Petersburg to some distance below Grant's Landing the ancient channel is now concealed by the drift on the Kentucky side. Laughery creek, after receiving the Sugar creek tributary two miles below Aurora, and Hogan's creek at that town, flowed north into the broad valley now held by the Great Miami; but instead of following the present bed of that stream (with a reversed current, of course), it held the same general direction with which it entered the valley, until on reaching the point (L) it swerved eastward, reaching the Great Miami valley again near the north line of Hamilton county at (E), and followed that valley to the city of Hamilton where it united with the Licking.

Beyond this place no examination has been made; but some ancient channels marked out in the reports of the Ohio Geological Survey indicate that the Licking received another tributary in this vicinity, made a detour to the east of Dayton, then bore northwest, past Troy. Prof. Tight has shown that Kanawha flowed north through the Scioto valley, and turned toward the northwest near Circleville; so Licking must have discharged into it in the neighborhood of Piqua.

THE FORMATION OF THE OHIO RIVER.

It will simplify an explanation to retain for the ancient drainage lines the names of the present streams, using them as they are used above.

The Great Kanawha held its way across Ohio until the glacier had advanced to that part of its valley which extended farthest to the northward. For a time the waters may have skirted the ice-front and recovered their natural channel farther

down ; but presently the valley was completely closed and the imprisoned waters found no escape until they had reached the level of the col at (K), on the divide between Sugar creek and Kentucky river.

This narrow pass, however, was much too small to carry off the drainage of many thousands of square miles, and its capacity was still further decreased by ice-bergs carried hither by the currents and gorged between its walls so the water accumulated until only the tops of the higher hills remained above its surface. Blocks of ice, broken from the glacier front, floated about in the lake, most of them depositing within a comparatively short distance the glacial debris which they carried ; others, much smaller perhaps, drifted many miles before they grounded on a drowned hill-top and left a boulder or a mass of gravel to puzzle a future geologist by its isolated position, so far from any moraine.

As the lake rose, other outlets would be reached at various levels higher than the col at Sugar creek ; finally the overflow would balance the accumulation. When the new channel was cleared of ice, and torn wider and deeper by a torrent like Niagara, the lake would begin to recede, the minor outlets would be abandoned, and all the discharge pass through the Sugar creek gap.

At this stage began the readjustment of drainage channels. The first change was in that part farthest west. Kanawha, shut off from its natural outlet toward the west, turned into Licking ; followed that valley southward to Hamilton ; turned into Laughery creek ; and thus reached the gorge at (K). But the stream was to have short tenure of its new quarters ; the advancing ice soon choked up the mouth of the Licking, and Kanawha was again deprived of an outlet. A second lake was formed, including the basin of Kanawha and all its tributaries east of Licking. The Monongahela, in pre-glacial times, had its outlet in the present Lake Erie ; it, too. had been shut off, and compelled to break a way from its old bed at Beaver, Penn., to the Kanawha at Huntington, West Va. At whatever time this occurred, it was certainly previous to the formation of

the second lake in Kanawha; so this additional amount of water was also to be disposed of. Consequently it would require only a short time for the resulting lake to find its way up Kinniconnick creek to the mouth of Cabin creek, or to the col separating those two streams, break over into Cabin, fill that valley and then rush over the divide between it and Limestone creek and follow the latter to its junction with Licking at the point (B), north to Hamilton, thence out Sugar creek.

In the course of time the steadily encroaching glacier covered the country about Hamilton; and for the third time a lake was formed. Both Kanawha and Licking were now shut off; their waters rose over the col at (D), and pushing through the narrow valley beyond, made their way out to Laughery creek at either (E) or (F), or possibly in both directions for a time; for even had the original point of discharge for this ravine been at (E) the glacial floods would by this time have torn a way through and thus established the present course of the Great Miami.

Still a fourth time was Kanawha to have its outlet shut off and its rapid current converted into a tranquil lake. The glacier came to the hills around Cincinnati; when this happened the old mouth of Limestone at (B) was obliterated, and Kanawha was compelled to make a new course for itself by tearing out the col at (C). Joining Licking again, the two followed their last channel as far as North Bend, and probably out to (F); but there is a possibility that before the col at (C) was removed the ice had advanced far enough to reach the hills south of (F). In this case the new lake would have included Licking valley and risen to the level of the col at (G) before it could have begun to drain off.

NOTE.—How many intervening cols were broken through by the Monongahela in its passage to Kanawha, or how many lakes and lakelets were successively formed and drained, can not yet be told; but to judge from the numerous sharp bends in that part of the Ohio, they must have been frequent. This is a factor to be taken into consideration, in studying the terraces of the upper Ohio and its branches.

If, however, the col at (C) was worn down in time for the water above it to escape through (F), then a fifth lake covered the upper Ohio valley before the col at (G) was eroded and the present drainage to the mouth of the great Miami established; and there may have been still a sixth lake, though if there was, it was of less extent and shorter duration than any of the others. The abandoned channel (H) back of Petersburg, seems due to a projection or "loop" of the glacier pushing out of Miami valley far enough to act as a dam to the new Ohio—which name is now first applicable to the river—and holding it back until its waters broke over the low divide that stood between old Laughery creek, and the ravine that came into the latter from the point (G). This is the only evidence that the ice ever reached the Kentucky side of the river, and it was not of suffi cient thickness to raise the water to the table-land.

It is not to be supposed that each of these successive lakes was drained before the next was formed; it is more probable that the gorge at (K) retained sufficient height to keep the present bottom lands, at least the lower ones, continually submerged until long after the ice had begun its retreat. Neither is it necessary to assume a constant forward motion of the glacier; its advance may have been frequently interrupted, or there may even have been an occasional recession, without in the least invalidating the argument. The effect would be the same in the end, whether there was a continuous progressive motion, or an intermittent action.

As nothing to the contrary has been said so far, it might be inferred that the Ohio, after first surmounting the col at (K) had an unchecked course to the Mississippi; but such was not the case. Kentucky river, Salt river (below Louisville), and possibly others, had a northward trend across the present Ohio valley into the state of Indiana. It is not known as yet, where they may have gone; but it is certain that their outlets were choked up by the ice as were those of Kanawha and Licking. They had to find their way out in the same manner and by the same means. Of this, the canon at Leavenworth is ample evidence; and it is not until the mouth of Green river is reached,

near Evansville, that a pre-glacial stream of any importance is to be found in the bed of the Ohio.

THE PROBABLE SOUTHERN LIMIT OF THE ICE-SHEET.

Charts of the terminal moraine represent it as crossing the Ohio River at four different points.

It is doubtful whether the glacier ever reached the left bank of that stream except as a spur from the mouth of the Great Miami.

If this opinion were made in the form of a definite assertion, it would need to be supported by a very distinct record of accurate observations; and these I have been unable to make. It is permissible for me, however, to present the reasons for my belief, leaving them to be confirmed or refuted, as they may deserve, by those who will have an opportunity for making a thorough investigation of the region.

Glacial drift has been found in quantity on the hills about Cincinnati; at "Split Rock;" and about the mouth of Kentucky river. These points have been connected, on some charts, by a line approximately straight; and this line is called the terminal moraine. It may be; I do not wish, at present, to say that it is not. But on such limited portion of the ground as I have had a chance to examine, I can find no evidence that it is a fact. There is no drift in Hogan's creek, at Aurora, at a greater height than it is to be found in the opposite Kentucky bottoms. There is none on the hills just south of that town. There is none in the valley of Laughery creek below the town of Hartford, eight miles from its mouth, except one small mass which is plainly a water deposit. There is none in the ravines or along the hill-sides on the road from Hartford to Rising Sun. Yet the maps show that all this area, except in the vicinity of Rising Sun, was under the ice-sheet. The heavy deposit about the mouth of Woolper's creek, known as "Split Rock" and "Kirby's Rock," (I), which is called the moraine, is not a moraine and has no resemblance to a moraine except at the western face—which part is plainly visible from the river. Fifty feet back from this face, along the south side of Wool-

per's, the character of the deposit is clearly shown; it is simply a mass of detritus carried by a torrent into a body of dead water. The dead water was the glacial lake created by the col at (K); the torrent was that which poured through the gap back of Petersburg (H) in the final effort of the Ohio to carve out its channel. Following the north side of the base of "Kirby Rock" (which is the proper one for study, "Split Rock" being insignificant by comparison), it will be found that the large stones disappear within a few rods and are succeeded by cobble-stones; these by gravel which grows smaller until it runs out in beds of sand; the sand, in turn, is soon replaced by the finest silt, resting against the limestone hill-side; and above this there is nothing resembling glacial drift, as far as the brow of the hill.

Of what may be on the table-land, I have no knowledge. In the report of the Indiana Geological Survey for 1878, it is stated that the hill-tops south and south-east of Middle creek—which enters the Ohio opposite Rising Sun—are capped with conglomerate similar to that at "Split Rock." I did not know of this at the time of my visit to the locality; it is probably due to ice-berg deposits at the beginning of the overflow at (K). Four miles below Grant's creek (J) the Ohio valley is quite narrow; on the Indiana side evenly stratified glacial material is piled to the height of at least 100 feet. It is of the same general character as the terraces existing throughout the valley of the Ohio and many of its tributaries, and is what is usually classed as belonging to the "Champlain period," following the "glacial period." The name is immaterial; but it is an error to suppose that the one era ended before the other began. On the contrary, they were synchronous; as soon as the outlet of old Kanawha was blocked glacial debris began to settle in the resultant lake-bed. The old river-beds were filled with it to a higher level than it is now to be found. Had there been no subsequent drainage, these valleys would now be plains having practically uniform surfaces. The present streams, however, in winding their way from side to side through them have alternately cut down and filled up, exactly as we may see every day

near Evansville, that a pre-glacial stream of any importance is to be found in the bed of the Ohio.

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in any little creek, until our existing terraces stand as witnesses to their energy.

At different times and places in the three southeastern counties of Indiana, men who seemed to know what they were talking about, agreed in their statements that from Dillsboro almost exactly south to near Vevay, the hills are capped with boulders and gravel; and that none is to be found east of that line, except in the streams. Probably this is the real moraine. It remains an open question whether it crossed the Ohio near Vevay; or whether the material about the mouth of the Kentucky river may not have accumulated in the same manner as at "Split Rock," namely, by ice-borne and torrential deposit in a temporary lake caused by a col below Madison, Indiana.

In all cases where drift is reported as existing on the "high lands," or the "highest hills," the person who essays to complete this unfinished work, should take pains to ascertain just how high they are. The suggestion seems scarcely necessary; but in reading some of the articles on this matter one would infer that water, instead of hunting the lowest places and flowing through, sought the highest places and climbed over.

EDITORIAL NOTE.—Since the presentation of Mr. Fowler's article before the Ohio State Academy of Science I have had the pleasure, through the kindness of the Cincinnati Society of Natural History, to visit the region around Cincinnati discussed by Mr Fowke and I take pleasure in stating that I believe Mr. Fowke has presented the best correlation of the complicated topographical features of the Cincinnati district that has been offered up to date. His broad generalizations as to the sequence of events are certainly suggestive of the vast amount of field work yet to be done before the full history can be written.

FOWKE—Preglacial Drainage near Cincinnati.